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(54) A system for locating automatically video segment boundaries and for extraction of key-frames

(57) The present invention describes an automatic video content parser for parsing video shots such that they are represented in their native media and retrievable based on their visual contents. This system provides methods for temporal segmentation of video sequences into individual camera shots using a novel twin-comparison method. The method is capable of detecting both camera shots implemented by sharp break and gradual transitions implemented by special editing techniques, including dissolve, wipe, fade-in and fade-out; and content based key frame selection of individual shots by analysing the temporal variation of video content and select a key frame once the difference of content between the current frame and a preceding selected key frame exceeds a set of preselected thresholds.

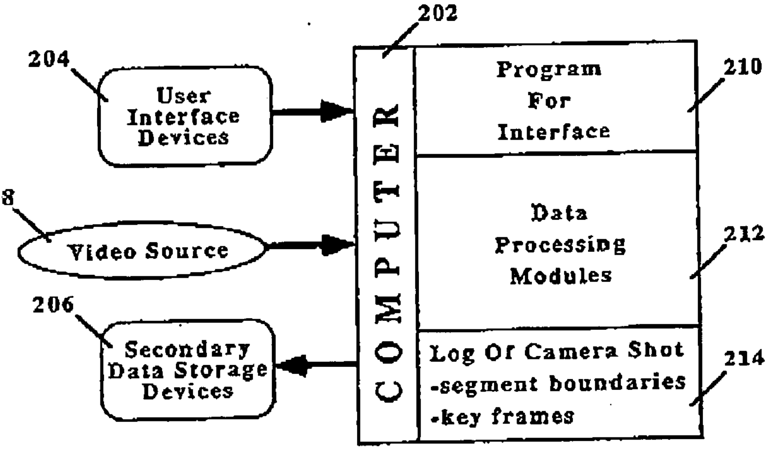

FIG. 2

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Description

The present invention relates to video indexing, archiving, editing and production, and, more particularly, this invention teaches a system for parsing video content automatically.

In today's information world, the importance of acquiring the right information quickly is an essential aspect we all face. Given so much information and databases to process, how do we make full use of the technological advancement to our advantage is what this present invention is addressing. Information about many major aspects of the world, in many cases, can only be successfully managed when presented in a time-varying manner such as video sources. However, the effective use of video sources is seriously limited by a lack of viable systems that enable easy and effective organization and retrieval of information from these sources. Also, the time-dependent nature of video makes it a very difficult medium to manage. Much of the vast quantity of video containing valuable information remains unindexed. This is because indexing requires an operator to view the entire video package and to assign index means manually to each of its scenes. Obviously, this approach is not feasible considering the abundance of unindexed videos and the lack of sufficient manpower and time. Moreover, without an index, information retrieval from video requires an operator to view the source during a sequential scan, but this process is slow and unreliable, particularly when compared with analogous retrieval techniques based on text. Therefore, there is clearly a need to present a video package in very much the same way as a book with index structure and a table of content. Prior art teaches segmentation algorithm to detect sharp camera breaks, but no method detects gradual transitions implemented by special editing techniques including dissolve, wipe, fade-in and fade-out. Prior art such as "Automatic Video Indexing and Full-Video Search for Object Appearances," Proc. 2nd Working Conf. on Visual Databased Systems, Budapest, 1991, pp. 119-133 by A. Nagasaka and Y. Tanaka and "Video Handling Based on Structured Information for Hypermedia Systems," Proc. Int'l Conf. on Multimedia Information Systems, Singapore, 1991, pp. 333-344 by Y. Tonomura teach segment boundaries detection methods but only capable of detecting sharp camera breaks. Another important area of video indexing is to select a representative frame known as Key Frame. This selection process as taught by prior art is based on motion analysis of shots and is complicated and prone to noise.

It is therfore an object of the present invention to automate temporal segmentation (or partitioning) of video sequences into individual camera shots by distinguishing between sharp breaks and gradual transitions implemented by special effects. Such partition is the first step in video content indexing which is currently being carried out manually by an operator a time consuming, tedious and unreliable process.

It is another object of the present invention to provide content based key frame selection of individual shots for representing, indexing and retrieval of the shots in a multimedia manner.

Accordingly, the present invention describes an automatic video content parser for parsing video shots such that they are represented in their native media and retrievable based on their visual contents. This system provides methods for temporal segmentation of video sequences into individual camera shots using a twin-comparison method. This method detects both camera shots implemented by sharp break and gradual transitions implemented by special editing techniques, including dissolve, wipe, fade-in and fade-out. The system also provides content based key frame selection of individual shots by analysing the temporal variation of video content and selects a key frame once the difference of content between the current frame and a preceding selected key frame exceeds a set of preselected thresholds.

For a better understanding of the present invention and to show how the same may be carried into effect reference will now be made by way of example to the accompanying drawings in which:-

FIG. 1A shows a flow chart of a known video segmentation method.

FIG. 1B shows an example of a typical sharp cut in a video sequence.

FIG. 2 is a block diagram showing an overview of a video content parsing system of the present invention.

FIG. 3A shows a flow chart for performing temporal segmentation capable of both detecting sharp cuts and gradual transitions implemented by special effects of the present invention.

FIG. 3B shows an example of a typical dissolve transition found in a video sequence.

FIG. 3C shows an example of the frame-to-frame difference values with high peaks corresponding to sharp cuts and a sequence of medium peaks corresponding to a typical dissolve sequence.

FIG. 4 shows a flow chart for extracting key frame of the present invention.

FIG. 5 shows a flow chart of a system for automatically segmenting video and extracting key frame according to the video parser in FIG. 2.

Various terminologies are used in the description of this present invention. Accordingly, for better understanding of the invention, definition of some of these terminologies are given as follows.

A "segment" or a "cut" is a single, uninterrupted camera shot, consisting of one or more frames.

A "transition" occurs when one moves from one segment to another in a video sequence. This could be implemented as a sharp break (occurs between two frames belonging to two different shots), or as special effects such as dissolve, wipe, fade-in and fade-out in which case, transition occurs across more than one frames.

"Temporal segmentation" or "scene change detection" of a video is to partition a given video sequence temporally into individual segments by finding the boundary positions between successive shots.

"Key frames" are those video frames which are extracted from a video segment to represent the content of the video or segment in video database. The number of key frames extracted from a video sequence is always smaller than the number of frames in the video sequence. Thus, a sequence of key frames is considered an abstraction of the video sequence from which they are extracted.

"Threshold" is a limiter used as a reference for checking to see whether a certain property has satisfied a certain criteria which is dictated by this limiter to define a boundary of a property. The value of threshold *t*, used in pair-wise comparison for judging whether a pixel or super-pixel has changed across successive frames is determined experimentally and it does not change significantly or different video sources. However, experiments have shown that the thresholds T_b and T_t used for determining a segment boundary using any of the difference metric (as defined below) varies from one video source to another.

"Difference metrics" are mathematical equations, or modifications thereof, adapted for analysing the properties of, in this case, video content. The different difference metrics includes:

- Pair-wise pixel comparison, whereby a pixel is judged as changed if the diference between the intensity values in the two frames exceeds a given threshold t. This metric may be represented as a binary function $DP_i(k,l)$ over the domain of two-dimensional coordinates of pixels, (k,l), where the subscript i denotes the index of the frame being compared with its successor. If $P_i(k,l)$ denotes the intensity value of the pixel at coordinate (k,l) in frame i, then $DP_i(k,l)$ may be defined as:

$$DP_i(k,l) = \begin{cases} 1 & \text{if } \left|P_i(k,l) - P_{i+1}(k,l)\right| > t \\ 0 & \text{otherwise} \end{cases}$$

The pair-wise comparison algorithm simply counts the number of pixels changed from one frame to the next according to the above metric. A segment boundary is declared if more than a given percentage of the total number of pixels (given as a threshold *T*) have changed. Since the total number of pixels in a frame of dimension M by N is $M*N$, this condition may be represented by the following inequality:

$$\frac{\sum_{k,l=1}^{M,N} DP_i(k,l)}{M*N} * 100 > T$$

- Likelihood ratio is a comparison of corresponding regions or blocks in two successive frames based on the second-order statistical characteristics of their intensity values. Let m_i and m_{i+1} denote the mean intensity values for a given region in two consecutive frames, and let S_i and S_{i+1} denote the corresponding variances and the ratio is defined as:

$$\frac{\left[\frac{S_i + S_{i+1}}{2} + \left(\frac{m_i - m_{i+1}}{2}\right)^2\right]^2}{S_i * S_{i+1}} > t$$

A segment boundary is declared whenever the total number of sample areas whose likelihood ratio exceeds the threshold t is sufficiently large (where "sufficiently large" depends on how the frame is partitioned). This metric is more immune to small and slow object motion moving from frame to frame than the preceding difference metrics and therefore less likely to be misinterpreted as camera breaks.

- Histogram comparison is yet another algorithm that is less sensitive to object motion, since it ignores the spatial changes in a frame. Let $H_i(j)$ denotes the histogram value for the *ith* frame, where *j* is one of the *G* possible pixel values. The overall difference SD_i is given by:

$$SD_i = \sum_{j=1}^{G} \left|H_i(j) - H_{i+j}(j)\right|$$

A segment boundary is declared once SD_i is greater than a given threshold *T*.

- χ^2 - test is a modified version of above immediate equation which makes the histogram comparison reflect the difference between two frames more strongly.

$$SD_i = \sum_{j=1}^{G} \frac{|H_i(j) - H_{i+j}(j)|^2}{H_{i+j}(j)}$$

These above metrics may be implemented with different modifications to accommodate the idiosyncrasies of different video sources. Unlike prior art, the video segmentation of the present invention does not limit itself to any particular difference metric and a single specified threshold. As such it is versatile.

FIG. 1A shows a flow chart of known video segmentation method. This algorithm detects sharp cuts in video sequences. This is achieved by first, after initializing the standard system parameters at block 101, a first reference frame is selected at block 102, the difference, D_i, between frames F_i and F_{i+S} (which is a skip factor S away) is calculated based on a selected difference metric at block 104. If D_i is greater than a preset threshold, a change of shot is detected and recorded at block 106 before proceeding to block 108. Otherwise, it proceeds directly to block 108 to establish a new frame. If it is the last frame, the segmentation process is completed; otherwise, it proceeds to block 103 to repeat the process until the last frame of the video sequence is reached. The output is a list of frame numbers and/or time codes of the starting and ending frames of each shot detected from the input video sequence. This method is only suitable for use in detecting sharp transition between camera shots in a video or film such as that depicted in FIG. 1B. The content between shot 110 and shot 112 is completely different from one another.

FIG. 2 is a block diagram showing an overview of a video content parsing system of the present invention. The system comprises of a computer 202, containing Program for Interface block 210, Data Processing Modules, block 212 for carrying out the preferred embodiments of the present invention, and block 214 for logging the information associated with segment boundaries and key frames. Connected to the computer are: User Interface Devices 204, an optional Secondary Data Storage Devices 206 and an input Video Source 208. The input video data can be either analog or digital, compressed or uncompressed and can be on any type of storage medium. This system can also receive any type of video/TV/film standard.

A. First Embodiment of Invention

FIG. 3A shows a flow chart for performing temporal segmentation capable of both detecting sharp cuts and gradual transitions implemented by special effects of the first embodiment of the present invention. This embodiment is different from the above described video segmentation algorithm of FIG. 1A. It is detects sophisticated transition techniques including dissolve, wipe, fade-in, and fade-out by using a novel twin-comparison method to find the starting and ending points of the transitions. Prior art by Tonomura employed a histogram difference metric to calculate the difference value between frames and to detect a scene change whenever the result is greater than a specified threshold. In contrast, the present invention does not limit itself by the use of any particular difference metric and a single specified threshold. The novel twin-comparison method uses more than one thresholds to detect both sharp camera breaks and gradual transitions. It introduces another diference comparison namely accumulated difference comparison as depicted in FIG. 3A.

Refering again to FIG. 3A, after initialization of system parameters at block 302, and loaded in frame i (current frame) at block 304, the detection process begins to compare previous frame i-S and current frame i by calculating the difference, D_i, based on a selected difference metric at block 306. If D_i is greater than a preselected shot break threshold, T_b, and *Trans* is *false* (that is, not in a transition period yet), then, it proceeds to block 308; otherwise, it goes to block 314. At block 308, if Σ_F, frame count in a shot, is not greater than N_{smin}, minimum number of frame for a shot, then it proceeds to block 315 where Σ_F is incremented by S, a temporal skip factor between two frames being compared in the detection before continuing to process the remaining frames in the video sequence at block 336; otherwise a cut is declared at point *P1* and a shot starting at frame F_s and ending at frame F_e is recorded at block 310 follow by reinitialization of the start of a new frame, reset frame count, Σ_F, to zero and set *Trans* to *false* at block 312 before proceeding to block 336. At block 314, D_i is checked against a larger threshold αT_b, where α is a user tunable parameter and is greater than 1. If D_i is greater and T*rans* is *true* then a comfirmed cut is declared at point *P1*; otherwise, it proceeds to block 316. Here, if *Trans* is found to be false, that is, not in a transition period, D_i is compared against a predefined transition break threshold, T_t, at block 330. If D_i is greater than T_t and the number of frame count in a shot, Σ_F, is greater than the minimum number of frame for a shot, N_{smin}, at block 332, a potential transition is found at *P2* and duely *Trans* is set to *true* and other relevant parameters are updated at block 334 before proceeding to block 335. Otherwise, it goes to block 355 where Σ_F is incremented by S before continuing to process the remaining frames in the video sequence. However, if, at block 316, *Trans* is *true*, that is, it is in a transition period, D_i is further compared against T_t. If it is not lesser, then, Σ_F (frame count in a shot), Σ_{td} (accumulative differences in a transition sequence) and Σ_{tF} (frame count in a transition process) are updated at block 317 before continuing to process the remaining frames in the video sequence; otherwise, it proceeds to calculate D_s, the difference between current frame i and start frame of the potential transition, F_p, that is, between image feature of current frame, f_i, and image feature of the potential transition frame, f_p. At block 318, if D_s is not greater than T_b or Σ_{ts}/Σ_{tF} is not greater then γT_t (where $\gamma \geq 1$) it goes to block 320; otherwise, the end of a transition has been successfully detected at point $P3$. Accordingly, a transition starting at F_s=F_p and ending at F_s is declared and recorded at block 322 before reinitializing relevant parameters at blocks 324 and 326 and then continues to process the next frame in the video sequence. At block 320, if the number of failed frame count for the period of transition, Σ_{tm}, is not less than the maximum allowable number of fails in a transition, N_{tmmax}, then the current transition is found to be falsed and deemed failed at block 328 at point $P4$; otherwise, Σ_{tm}, Σ_{ts} and Σ_{tF} are updated, that is, still in transition period, before proceeding to block 336. Here, the position of the current frame is incremented by a pre-defined skip factor, S, the start of the next frame for processing; and if it has not reached the end of the frame in the sequence, then repeat the process from block 304.

The flow chart as depicted in FIG. 3A is capable of detecting gradual transitions such as a dissolve as shown in FIG. 3B. The original scene 340 is slowly being superimposed by another scene at 342, 344 and 346 and finally fully dominated by that new scene 348. Effectively, the task of the algorithm as described above is to detect these first and last frames of the transition sequences in a video sequence. FIG. 3C depicts an example of the frame-to-frame difference values, showing high peaks corresponding to sharp cuts at 350 and 352; and a sequence of medium peaks corresponding to a typical dissolve sequence 354.

A single-pass approach depicted in FIG. 3A has disadvantage of not exploiting any information other than the threshold values, thus, this approach depends heavily on the selection of those values. Also, the processing speed is slow. A straightforward approach to reducing processing time is to lower the resolution of the comparison, that is, examining only a subset of the total number of pixels in each frame. However, this is clearly risky, since if the subset is too small, the loss of spatial detail (if examining in spatial domain) may result in a failure to detect certain segment boundaries. A further improvement could be achieved by employing a novel multiple-pass approach to provide both high speed processing, the amount of improvement depends on the size of the skip factor and the number of passes, and accuracy of the same order in detecting segment boundaries. In the first pass, resolution is sacrified temporally to detect potential segment boundaries with high speed. That is, a "skip factor", S, in the video segmentation process is introduced. The larger the skip factor, the lower the resolution. (Note that this skip factor is in general larger than the one used in the description of the above and below flow charts.) For instance, a skip factor of 10 means examining only one out of 10 frames from the input video sequence, hence reducing the number of comparisons (and, therefore, the associated processing time) by the same factor. In this process twin comparison for gradual transitions as described in FIG. 3A is not applied. Instead, a lower value of T_b is used; and all frames having a difference larger than T_b are detected as potential segment boundary. Due to the lower threshold and large skip factor, both camera breaks and gradual transitions, as well as some artifacts due to camera or object movement, will be detected. False detections fall under the threshold will also be admitted, as long as no real boundaries are missed. In the second pass, all computations are restricted to the vicinity of these potential boundaries and the twin-comparison is applied. Increased temporal (and spatial) resolution is used to locate all boundaries (both camera breaks and gradual transitions) more accurately, thus recovers the drawback of the low accuracy of locating the potential shot boundaries resulting from the first pass. Another feature can be implemented in the multiple-pass method is that there is an option whereby different difference metrics may be applied in different passes to increase confidence in the results.

B. Second Embodiment of Invention

The second embodiment of the present invention pertains to the determination of the threshold values used for determining segment boundaries, in particular thresholds T_b, the shot break threshold, and T_t, the transition break threshold. It is of utmost importance when selecting these threshold values because it has been shown that they vary from one video source to another. A "tight" threshold makes it difficult for false transitions to be falsely accepted by the system, but at the risk of falsely rejecting true transitions. Conversely, a "loose" threshold enables transitions to be accepted consistently, but at the risk of falsely accepting false transitions.

In this invention, the automatic selection of threshold T_b is based on statistics of frame-to-frame differences over an entire or part of a given video sequence. Assuming that if there is no camera shot change or camera movement in a video sequence, the frame-to-frame difference value can only be due to three sources of noise: noise from digitizing the original analog video signal, noise introduced by video production equipment, and noise resulting from the physical fact that few objects remain perfectly still. All three sources of noise may be assumed to be random. Thus, the distribution of frame-to-frame differences can be decomposed into a sum of two parts: the random noises and the differences introduced by shot cut and gradual transitions. Differences due to noise do not relate to transitions. So T_b is defined as $T_b = \mu + a\sigma$ where σ is the standard deviation, μ is the mean difference from frame to frame and a is a tunable parameter and $a > 2$. The other threshold, namely, T_t, is used for detecting gradual transition and is defined as $T_t = bT_b$ where b

is between 0.1 to 0.5; according to experiments conducted.

C. Third Embodiment of Invention

FIG. 4 depicts the third embodiment of the présent invention, an automatic content based key frame extraction method using temporal variation of video content. After initializing system parameters at block 502, the difference, D_i, between frames i-S and i are calculated and accumulated based on a selected difference metric at block 506. If this accumulated difference, Σ_k, exceeds T_k, threshold for potential key frame, then, it sets the *Flag* to *1*, a potential key frame has been detected, at block 509 and proceeds to block 510, where further verification is made by calculating D_a, the difference between current frame i and last key frame recorded, F_k, based on a selected difference metric. If, at block 511, D_a is greater than T_d, threshold for key frame, then, at block 512, the current frame, F_i, is recorded as a current key frame and reinitialization of F_k as current frame, Σ_k to zero, and f_k, image feature of previous key frame, as current image feature is carried out before repeating the process again from block 504 if the end of the frame of the video sequence has not been reached. Otherwise, if, at block 511, D_a is not greater than T_d, then, it proceeds to analyse the next frame.

The key frame extaction method as described in FIG. 4 is different from prior art. Prior art uses motion analysis which heavily depends on tracing the positions and sizes of the objects being investigated using mathematical functions to extract a key frame. This method is not only too slow but also impractical since it relies on accurate motion field detection and complicated image warping. Whereas the present invention extracts key frames purely based on the temporal variation of the video content as described in FIG. 4. These key frames can then be used in video content indexing and retrieval.

OPERATION OF THE PREFERRED EMBODIMENTS

FIG. 5 shows a flow chart of an operation of the preferred embodiments for a video parser of FIG. 2. After selecting the difference metric(s) and therefore the image feature(s) to be used in frame content comparison, by user or by default, as well as all the required system parameters at block 602, the system loads in a video sequence into the parser, and digitize it if it has not been done so. Then, the difference, D_i, between consecutive video frames is calculated based on the selected difference metric(s) at block 608. If D_i exceeds the shot break threshold, T_b, and *Trans* is *false* (that is, not in a transition period) and the number of frame count in a shot, Σ_F, is greater than the minimum preset number of frames for a shot, N_{smin}, a cut is declared at point *P1* and a shot, starting at frame F_s and ending at frame F_e, is recorded; and the detection process continues to process the following frames of the video sequence. However, if, at block 612, Σ_F is not greater than N_{smin}, then, a key frame is recorded at block 614. At block 610, if the conditions are not true and at block 618, the conditions are still not true, then, further check is required at block 620. At this check, if *Trans* is not *true* and at block 646, D_i is not greater than T_t, then, it proceeds to block 640 where Σ_k, accumulative differences after previous key frame, is incremented by D_i and proceeds to block 641. Here, if the accumulative differences is not greater than T_b, it goes to block 638; otherwise it proceeds to block 650 to calculate D_a, the difference between feature f_i and f_p. If, at block 644, the number of frame count in a shot, Σ_F, is greater than the minimum number of frame allowable for a single shot, N_{smin}, a potential transition is found at *P2* and accordingly *Trans* is set to *true* and other relevant parameters are updated at block 642; otherwise, it proceeds to block 640. Coming back to block 652, if D_a is greater than δT_b, a key frame is detected at point *P5* and appropriately recorded at block 648; otherwise, it proceeds to block 638 where Σ_F is incremented by *S* before continuing to process the remaining frames in the video sequence. However, if, at block 620, *Trans* is *true*, that is, it is in a potential transition phase; and, at block 622, D_i is less than transition break threshold, T_t, a further distinction is achieved by calculating, D_a, the difference between the current feature, f_i, and previous feature, f_p, at block 624. At block 626, if D_a is greater than βD_i (where $\beta \geqq 2$) or the average of D_i between the frames in the potential transition, Σ_{td}/Σ_{tF}, is greater than γT_t (where $\gamma \geqq 1$), then, a transition is confirmed at point *P3*. A shot starting at frame F_s and ending at frame F_e ($=i$-Σ_{tF}) is recorded at block 628 before reinitialization of the relevant parameters at block 630. However, if, at block 626, the conditions are not true and at block 632, the number of failed frame count, Σ_{tm}, is not less than the maximum allowable number of fails in a transition, N_{tmmax}, then, a false transition is declared at point P4 and accordingly, *Trans* is set to *false* before proceeding to block 640. At block 632, however, if the condition is satisfied, it proceeds to blocks 636 and 638 where the parameters as adjusted accordingly before it continues to process the next frames within the video sequence. At block 622, if the condition is not met, it proceeds to block 621 where concerned parameters are adjusted accordingly before proceeding to process the following frames in the video sequence. The output data contains the frame numbers and/or time codes of the starting and ending frames as well as key frames of each shot.

While the present invention has been described particularly with reference to FIGS. 1 to 5, it should be understood that the figures are for illustration only and should not be taken as limitations on the invention. In addition, it is clear that the methods of the present invention have utility in many applications where analysis of image information is required.

It is contemplated that many changes and modifications may be made by one of ordinary skill in the art without departing from the spirit and the scope of the invention as described.

Claims

1. In a system for parsing a plurality of images in motion without modifying the media in which the images are recorded originally, said images being further divided into plurality sequences of frames, a method for selecting at least one key frame representative of a sequence of said images comprising the steps of:

    (a) determining a difference metric or a set of difference metrics between consecutive image frames, said difference metrics having corresponding thresholds;

    (b) deriving a content difference (D_i), said D_i being the difference between two current image frames and said difference metrics, the interval between said two current image frames being adjustable with a skip factor S which define the resolution at which said image frames are being analysed;

    (c) accumulating D_i between every two said consecutive frames until the sum thereof exceeds a predetermined potential key threshold T_k;

    (d) calculating a difference D_a, said D_a being the difference between the current frame and the previous key frame based on said difference metrics, or between the current frame and the first frame of said sequence based also on said difference metric if there is no previous key frame, the current frame becoming the key frame if D_a exceeds a predetermined key frame threshold T_d; and

    (e) continues the steps in (a) to (d) until the end frame is reached, whereby key frames for indexing sequences of image are identified and captured automatically.

2. In a system for parsing a plurality of images in motion without modifying the media in which the images are recorded originally, said images being further divided into plurality sequences of frames, a method for segmenting at least one sequence of said images into individual camera shots, said method comprising the steps of:

    (a) determining a difference metric or a set of difference metrics between consecutive image frames, said difference metrics having corresponding shot break thresholds T_b;

    (b) deriving a content difference (D_i), said D_i being the difference between two current image frames and said difference metrics, the interval between said two current image frames being adjustable with a skip factor S which define the resolution at which said image frames are being analysed;

    (c) declaring a sharp cut if D_i exceeds said threshold T_b;

    (d) detecting the starting frame of a potential transition if said D_i exceeds a transition threshold T_t but less than said shot break threshold T_b;

    (e) detecting the ending frame of a potential transition by verifying the accumulated difference, said accumulated difference being based on said selected difference metrics; and

    (f) continues the steps in (a) to (e) until the end frame is reached, whereby sequence of images having individual camera shots are identified and segmented automatically in at least one pass.

3. The method of video segmentation as in claim 2 wherein the processing speed of steps 4(a)-4(f) is enhanced with a multi-pass method, said multi-pass method comprising at least two steps:

    (a) in a first pass, resolution is temporarily decreased by choosing a substantially larger skip factor S and a lower shot break threshold T_b so as to identify rapidly the locations of potential segment boundaries without allowing any real boundaries to pass through without being detected; and

    (b) in subsequent passes, resolution is increased and all computation is restricted to the vicinity of said potential segment boundaries whereby both camera breaks and gradual transitions are further identified.

4. The method for video segmentation as in claim 3 wherein said multi-pass method can employ different difference metrics in different passes to increase confidence in the results.

5. The method for video segmentation as in claim 3 wherein said first pass does not apply steps 4(a)-4(f).

6. The method for video segmentation as in claim 3 wherein said subsequent passes apply said steps 4(a)-4(f).

7. In a system for parsing a plurality of images in motion without modifying the media in which the images are recorded originally, said images being further divided into plurality sequences of frames, a method for segmenting at least one sequence of said images into individual camera shots and selecting at least one key frame representative of a sequence of said images, said method comprising the steps of:

(a) determining a difference metric or a set of difference metrics between consecutive image frames, said difference metrics having corresponding shot break thresholds T_b;

(b) deriving a content difference (D_i), said D_i being the difference between two current image frames and said difference metrics, the interval between said two current image frames being adjustable with a skip factor S which define the resolution at which said image frames are being analysed;

(c) declaring a sharp cut if D_i exceeds said threshold T_b;

(d) detecting the starting frame of a potential transition if said D_i exceeds a transition threshold T_t but less than said shot break threshold T_b;

(e) detecting the ending frame of a potential transition by verifying the accumulated difference, said accumulated difference being based on said selected difference metrics;

(f) continues the steps in (a) to (e) until the end frame is reached;

(g) deriving a content difference (D_i), said D_i being the difference between two current image frames based on said selected image features and said difference metric, the interval between said two current image frames being adjustable with a skip factor S which define the resolution at which said image frames are being analysed;

(h) accumulating D_i between every two said consecutive frames until the sum thereof exceeds a predetermined potential key threshold T_k;

(i) calculating a difference D_a, said D_a being the difference between the current frame and the previous key frame based on said difference metric, or between the current frame and the first frame of said sequence based also on said difference metric if there is no previous key frame, the current frame becoming the key frame if D_a exceeds a predetermined key frame threshold T_d; and

(j) continues the steps in (a) to (i) until the end frame is reached, whereby sequence of images having individual camera shots are identified and segmented automatically and key frames for indexing sequences of image are identified and captured in at least one pass.

8. The method for video segmentation as in claims 2 and 7 wherein said shot break threshold T_b comprises a sum of the mean of the frame-to-frame difference μ and a multiple a of the standard deviation of the frame-to-frame diffemce σ.

9. The method for video segmentation as in claim 8 wherein said multiple a have a value between 5 and 6 when the difference metric is a histrogram comparison.

10. The method for video segmentation as in claims 2 and 7 wherein said transition threshold T_t comprises a sum of a multiple b of said shot break threshold T_b.

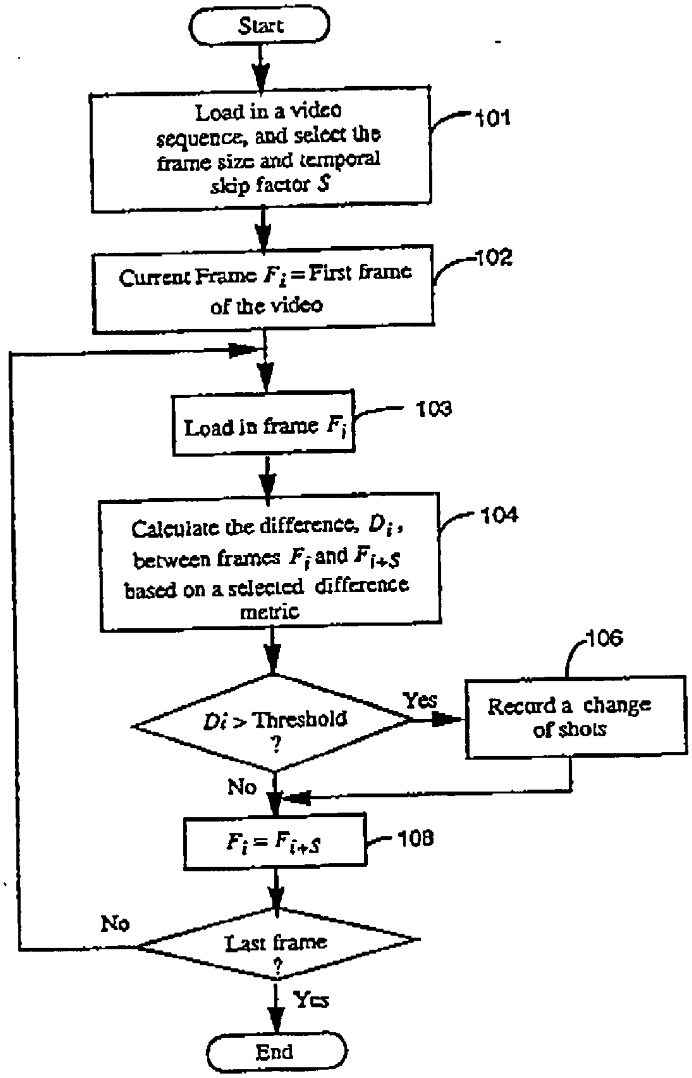

Start
Load in a video sequence, and select the frame size and temporal skip factor S
101
Current Frame F_i = First frame of the video
102
Load in frame F_i
103
Calculate the difference, D_i, between frames F_i and F_{i+S} based on a selected difference metric
104
106
Di > Threshold ?
Yes
Record a change of shots
No
$F_i = F_{i+S}$
108
No
Last frame ?
Yes
End

FIG.1A
(Prior Art)

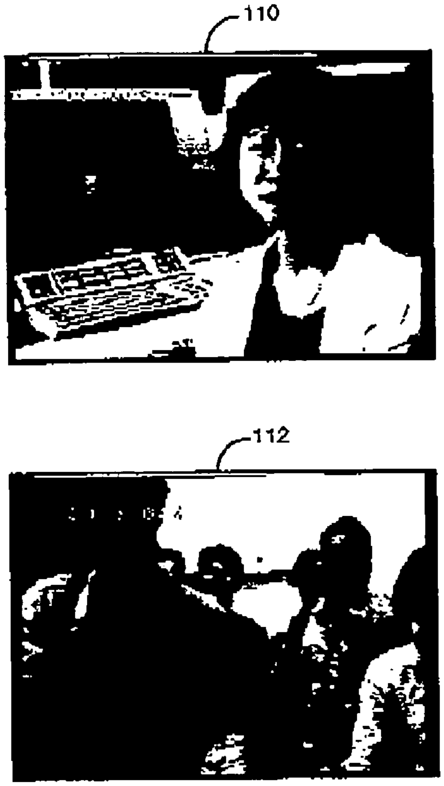


FIG.1B

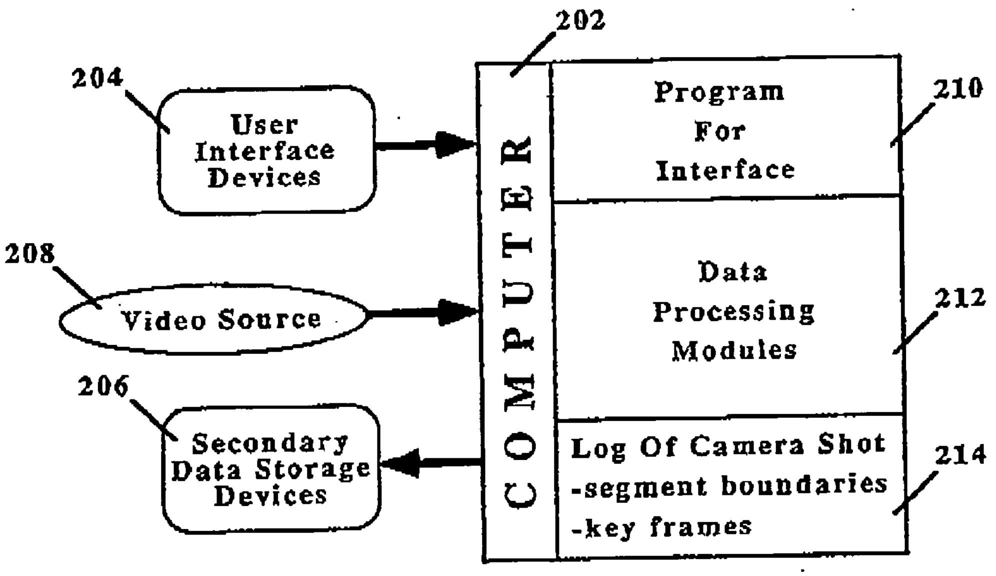

202
204
User Interface Devices
208
Video Source
206
Secondary Data Storage Devices
COMPUTER
Program For Interface
210
Data Processing Modules
212
Log Of Camera Shot
-segment boundaries
-key frames
214

FIG. 2

Note:
S: temporal skip-interval between two frames being compared in the detection;
S_F: frame size;
α, γ: user tunable parameters, $\alpha,\gamma>1.0$;
T_b: shot break threshold
T_t: transition break threshold
i: current frame; i -S: last frame;
F_S: start frame of a shot;
F_E: end frame of a shot;
F_p: start frame of a potential transition;
Trans: flag to indicate whether in a transition;
f_i: image feature of frame i;
f_p: image feature of frame F_p;
D_i: difference between frames i-S and i;
D_a: difference between frame F_i and Fp;
Σ_F: frame count in a shot;
Σ_{tm}: failed frame count in transition detection;
N_{smin}: minimum number of frames for a shot;
Σ_{tF}: frame count in a transition process;
Σ_{ta}: accumulative differences in a transition;
N_{tmmax}: Maximum of allowed fails in a trasition.

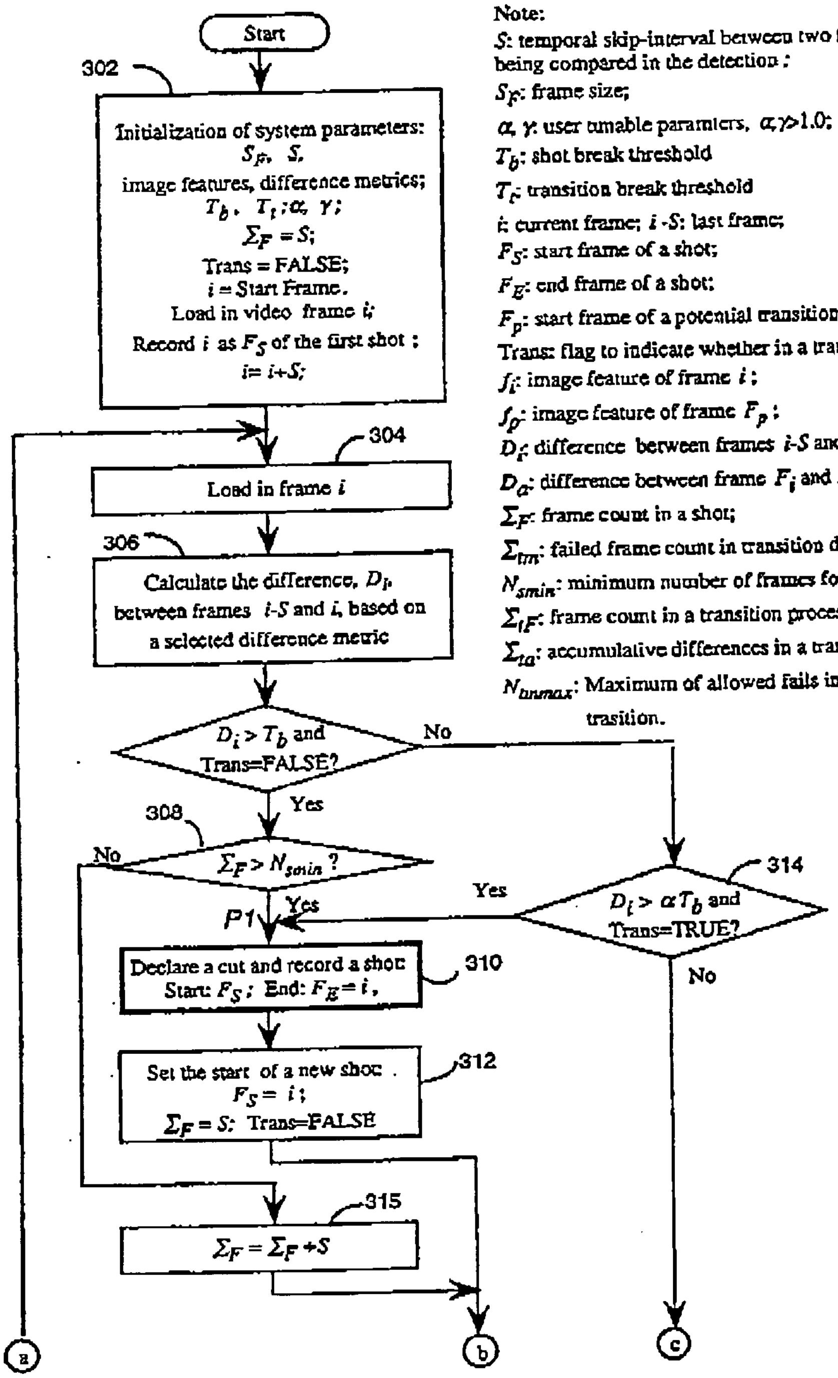

Start
302
Initialization of system parameters:
S_F, S,
image features, difference metrics;
T_b, T_t; α, γ;
$\Sigma_F = S$;
Trans = FALSE;
i = Start Frame.
Load in video frame i;
Record i as F_S of the first shot;
$i = i+S$;
304
Load in frame i
306
Calculate the difference, D_i, between frames i-S and i, based on a selected difference metric
$D_i > T_b$ and Trans=FALSE?
No
Yes
308
No
$\Sigma_F > N_{smin}$?
Yes
P1
Yes
314
$D_i > \alpha T_b$ and Trans=TRUE?
No
Declare a cut and record a shot
Start: F_S; End: $F_E = i$,
310
Set the start of a new shot .
$F_S = i$;
$\Sigma_F = S$; Trans=FALSE
312
315
$\Sigma_F = \Sigma_F + S$
a
b
c

FIG.3A

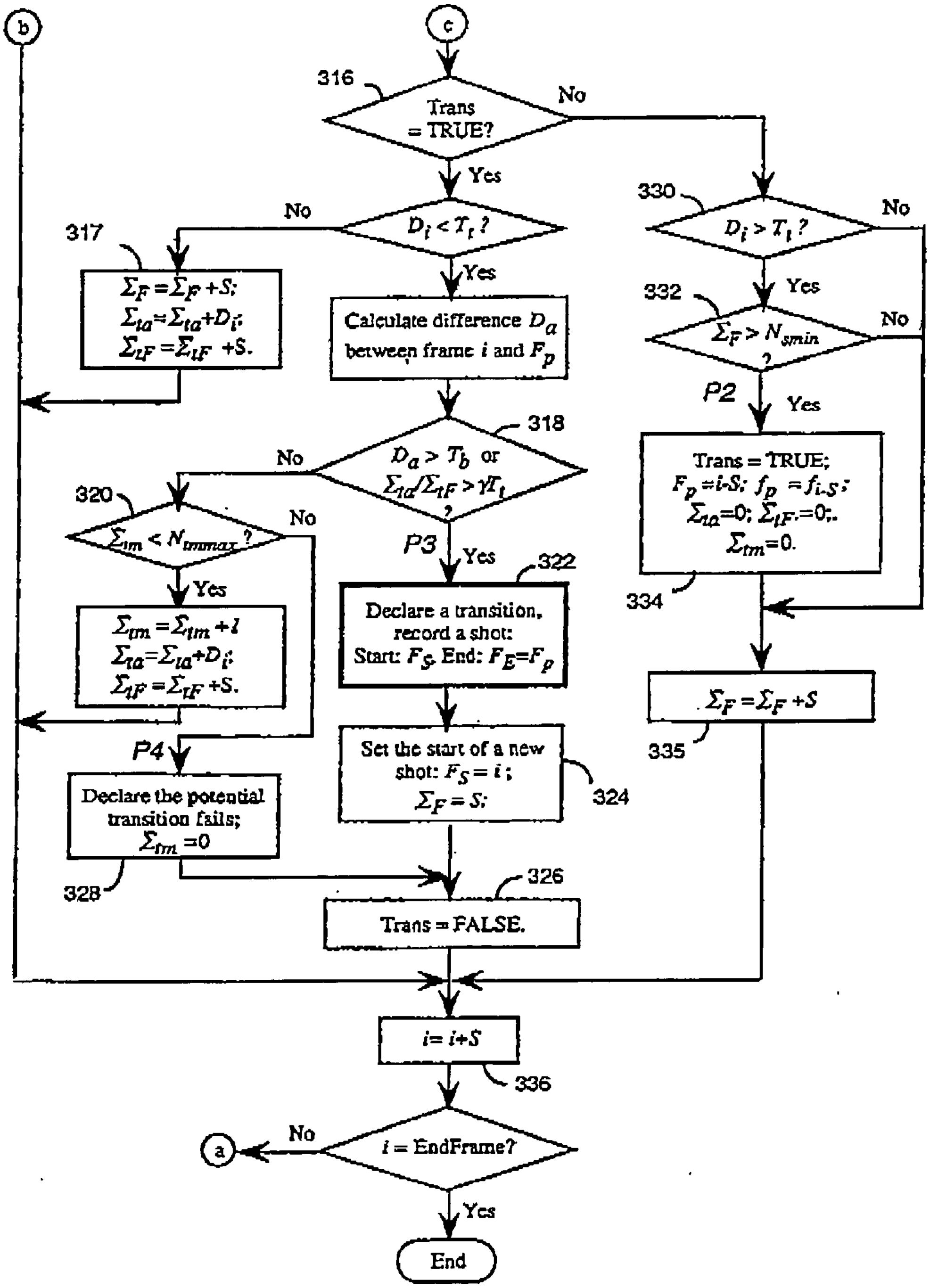

b
c
316
Trans = TRUE?
No
Yes
330
$D_i > T_t$?
No
Yes
332
$\Sigma_F > N_{smin}$?
No
P2
Yes
Trans = TRUE; $F_p = i\text{-}S$; $f_p = f_{i\text{-}S}$; $\Sigma_{ta}=0$; $\Sigma_{tF}=0$;. $\Sigma_{tm}=0$.
334
$\Sigma_F = \Sigma_F + S$
335
No
$D_i < T_t$?
Yes
317
$\Sigma_F = \Sigma_F + S$; $\Sigma_{ta} = \Sigma_{ta} + D_i$; $\Sigma_{tF} = \Sigma_{tF} + S$.
Calculate difference D_a between frame i and F_p
318
$D_a > T_b$ or $\Sigma_{ta}/\Sigma_{tF} > \gamma T_t$?
No
320
$\Sigma_{tm} < N_{tmmax}$?
No
Yes
$\Sigma_{tm} = \Sigma_{tm} + 1$ $\Sigma_{ta} = \Sigma_{ta} + D_i$; $\Sigma_{tF} = \Sigma_{tF} + S$.
P4
Declare the potential transition fails; $\Sigma_{tm} = 0$
328
P3
Yes
322
Declare a transition, record a shot: Start: F_S, End: $F_E = F_p$
Set the start of a new shot: $F_S = i$; $\Sigma_F = S$;
324
326
Trans = FALSE.
$i = i+S$
336
i = EndFrame?
No
a
Yes
End

FIG.3A (continued)

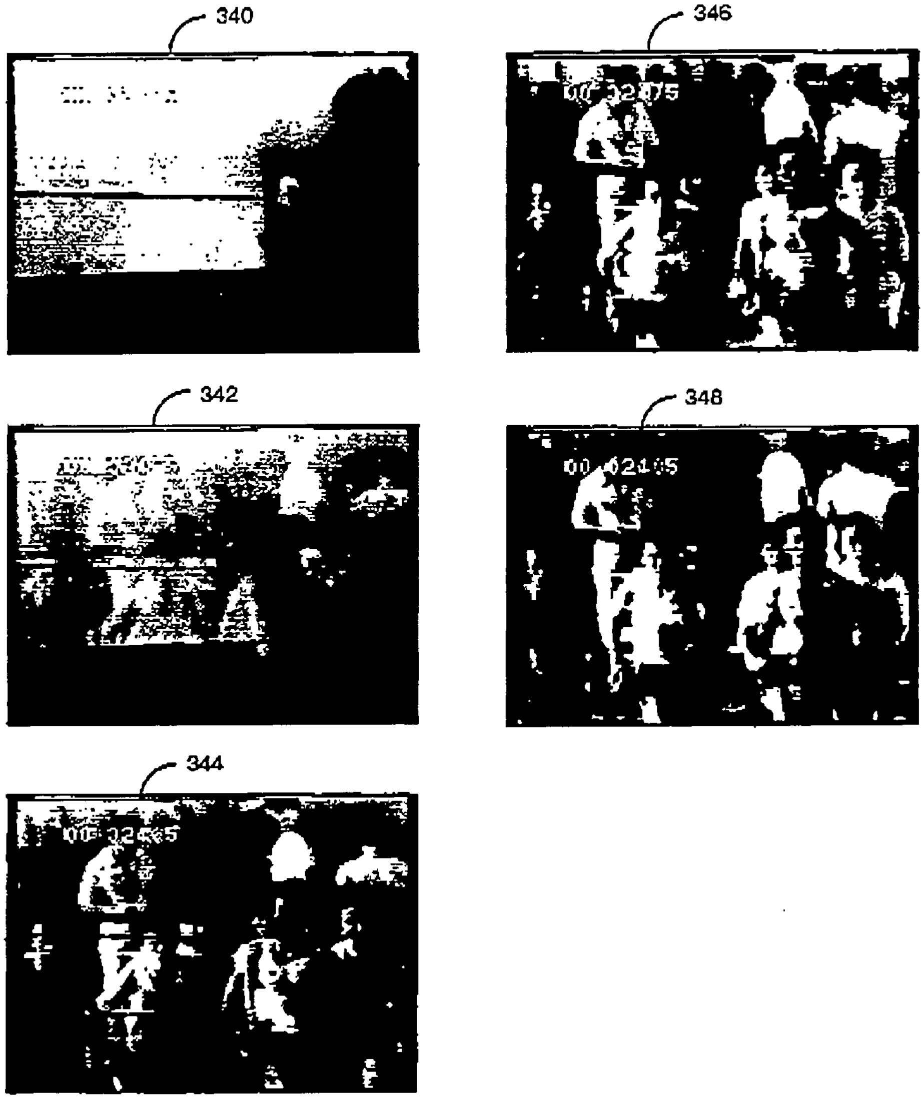


FIG.3B

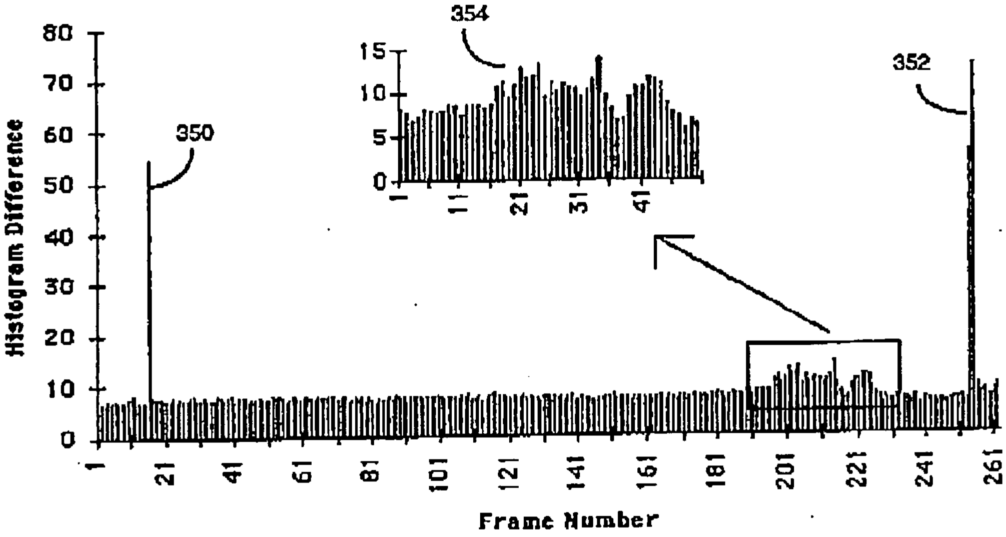
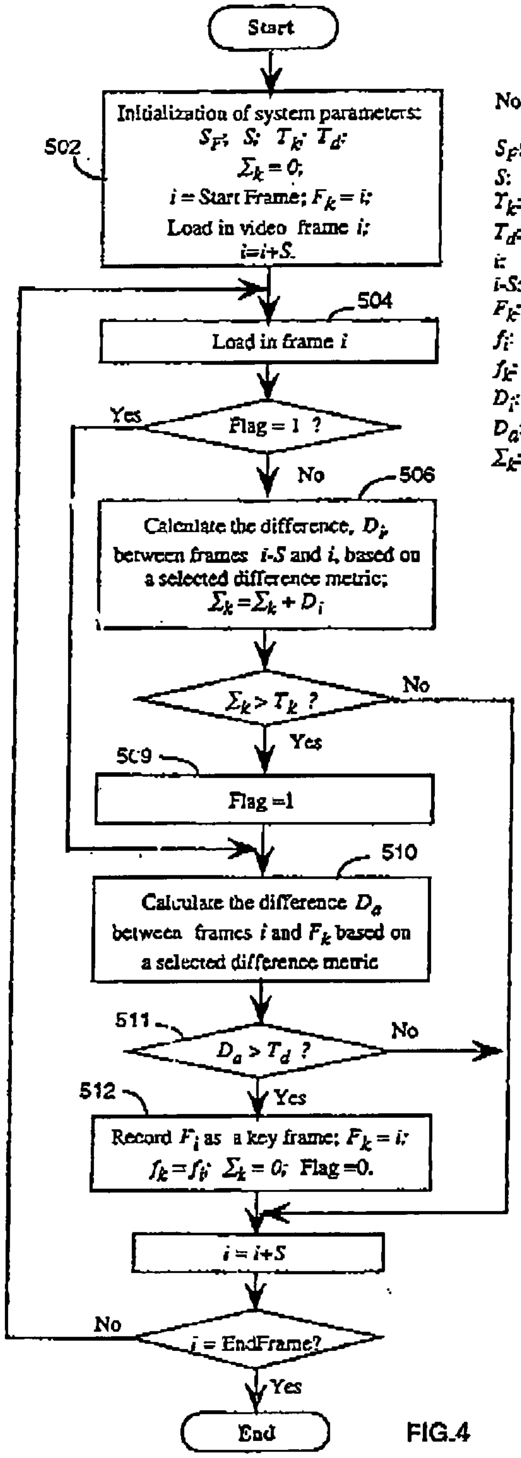

354
15
10
5
0
1
11
21
31
41
352
350
80
70
60
50
40
30
20
10
0
Histogram Difference
1
21
41
61
81
101
121
141
161
181
201
221
241
261
Frame Number

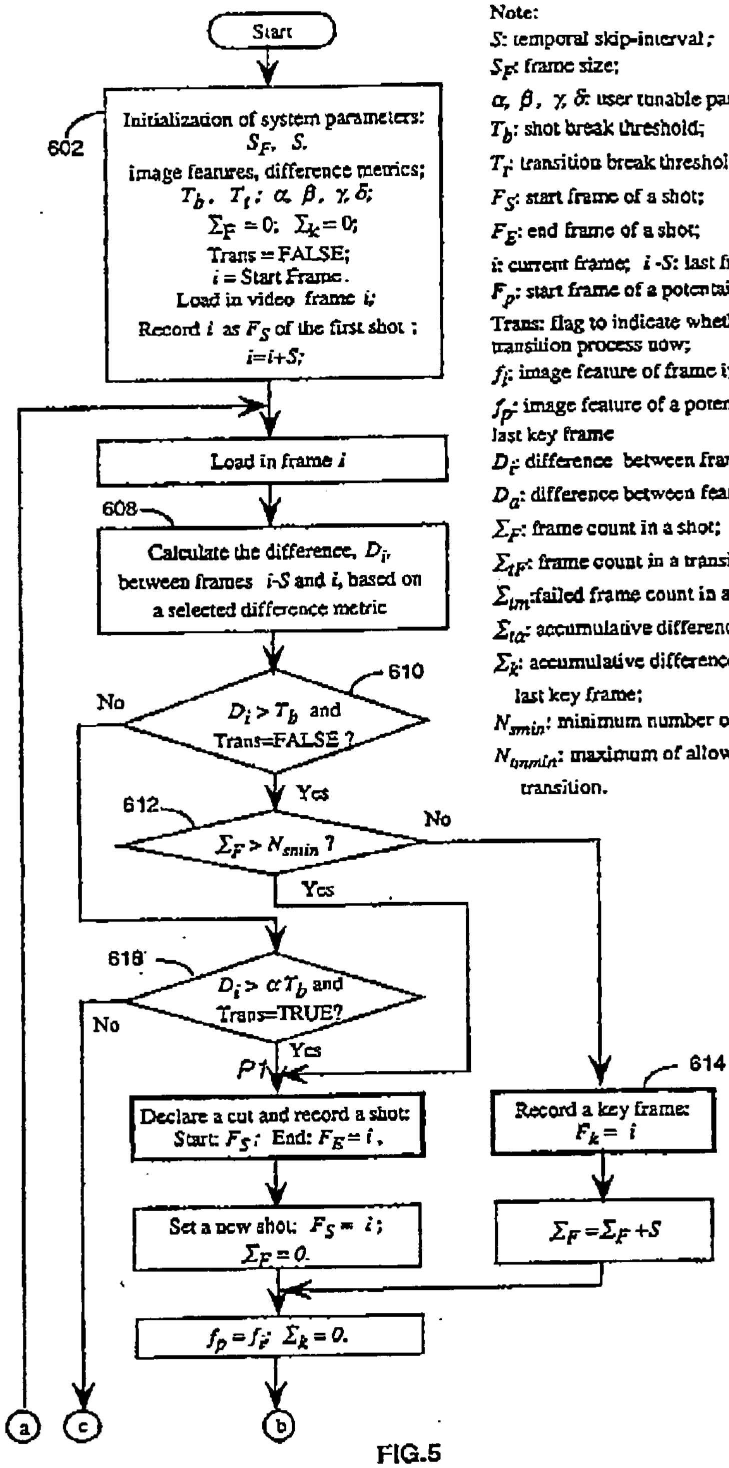
FIG.3C


Start
Initialization of system parameters:
S_F; S; T_k; T_d;
$\Sigma_k = 0$;
i = Start Frame; $F_k = i$;
Load in video frame i;
$i = i+S$.
502
504
Load in frame i
Yes
Flag = 1 ?
No
506
Calculate the difference, D_i,
between frames i-S and i, based on
a selected difference metric;
$\Sigma_k = \Sigma_k + D_i$
$\Sigma_k > T_k$?
No
Yes
509
Flag =1
510
Calculate the difference D_a
between frames i and F_k based on
a selected difference metric
511
$D_a > T_d$?
No
512
Yes
Record F_i as a key frame; $F_k = i$;
$f_k = f_i$; $\Sigma_k = 0$; Flag =0.
$i = i+S$
No
i = EndFrame?
Yes
End

Note:

S_F: frame size,
S: temporal skip factor ;
T_k: threshold for potentail key frame;
T_d: threshold for key frame;
i: current frame;
i-S: last frame;
F_k: last key frame recorded;
f_i: image feature of frame i;
f_k: image feature of previous key frame;
D_i: difference between frames i-S and i;
D_a: difference between frames F_k and i;
Σ_k: accumulative differences after
previous key frame;

FIG.4


Start
602
Initialization of system parameters:
S_F, S.
image features, difference metrics;
T_b, T_t: α, β, γ, δ;
$\Sigma_F = 0$; $\Sigma_k = 0$;
Trans = FALSE;
i = Start Frame.
Load in video frame i;
Record i as F_S of the first shot ;
$i=i+S$;
Load in frame i
608
Calculate the difference, D_i, between frames i-S and i, based on a selected difference metric
610
$D_i > T_b$ and Trans=FALSE ?
No
Yes
612
$\Sigma_F > N_{smin}$?
No
Yes
618
$D_i > \alpha T_b$ and Trans=TRUE?
No
Yes
P1
Declare a cut and record a shot: Start: F_S; End: $F_E = i$.
Set a new shot: $F_S = i$; $\Sigma_F = 0$.
614
Record a key frame: $F_k = i$
$\Sigma_F = \Sigma_F + S$
$f_p = f_i$; $\Sigma_k = 0$.
a
c
b

Note:
S: temporal skip-interval;
S_F: frame size;
α, β, γ, δ: user tunable paramters. $\alpha, \beta, \gamma \geq 1$;
T_b: shot break threshold;
T_t: transition break threshold
F_S: start frame of a shot;
F_E: end frame of a shot;
i: current frame; i-S: last frame;
F_p: start frame of a potentail trnation;
Trans: flag to indicate whether in potential transition process now;
f_i: image feature of frame i;
f_p: image feature of a potentail transition or the last key frame
D_i: difference between frames i-S and i;
D_a: difference between feature f_i and f_P;
Σ_F: frame count in a shot;
Σ_{tF}: frame count in a transition;
Σ_{tm}:failed frame count in a transition;
Σ_{ta}: accumulative differences in a transition;
Σ_k: accumulative differences after last key frame;
N_{smin}: minimum number of frames for a shot;
N_{tmmin}: maximum of allowed fails in a transition.

FIG.5

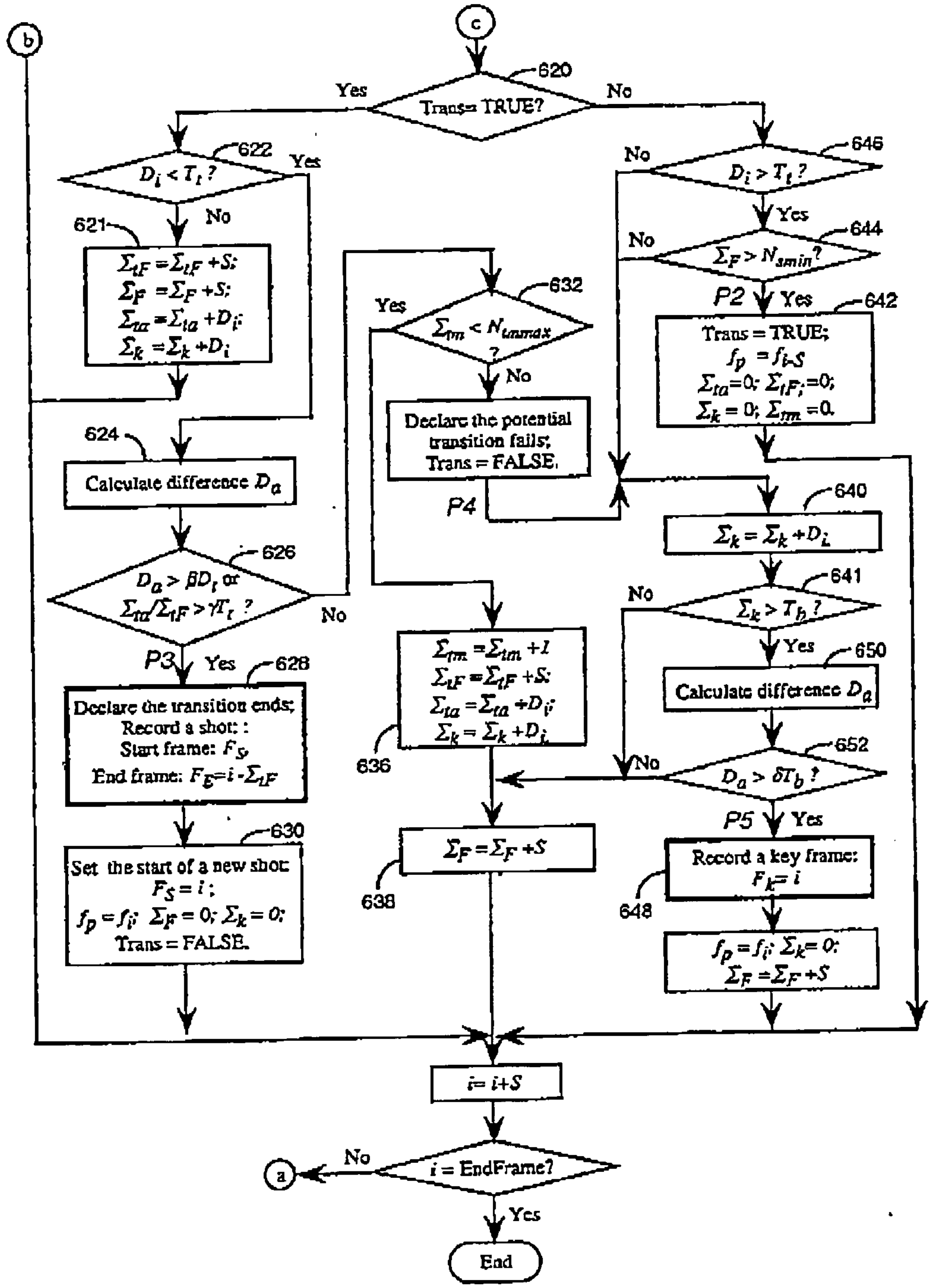

b
c
620
Yes
Trans= TRUE?
No
622
Yes
$D_i < T_t$?
No
621
$\Sigma_{tF} = \Sigma_{tF} + S;$
$\Sigma_F = \Sigma_F + S;$
$\Sigma_{ta} = \Sigma_{ta} + D_i;$
$\Sigma_k = \Sigma_k + D_i$
646
No
$D_i > T_t$?
Yes
644
No
$\Sigma_F > N_{smin}$?
P2
Yes
642
Trans = TRUE;
$f_p = f_{i-S}$
$\Sigma_{ta}=0; \Sigma_{tF}=0;$
$\Sigma_k = 0; \Sigma_{tm} = 0.$
632
Yes
$\Sigma_{tm} < N_{tmmax}$?
No
Declare the potential transition fails;
Trans = FALSE.
P4
624
Calculate difference D_a
640
$\Sigma_k = \Sigma_k + D_i$
626
$D_a > \beta D_t$ or
$\Sigma_{ta}/\Sigma_{tF} > \gamma T_t$?
No
641
No
$\Sigma_k > T_b$?
Yes
650
Calculate difference D_a
P3
Yes
628
Declare the transition ends;
Record a shot: :
Start frame: F_S,
End frame: $F_E = i - \Sigma_{tF}$
$\Sigma_{tm} = \Sigma_{tm} + 1$
$\Sigma_{tF} = \Sigma_{tF} + S;$
$\Sigma_{ta} = \Sigma_{ta} + D_i;$
$\Sigma_k = \Sigma_k + D_i$
636
652
No
$D_a > \delta T_b$?
P5
Yes
630
Set the start of a new shot:
$F_S = i$;
$f_p = f_i; \Sigma_F = 0; \Sigma_k = 0;$
Trans = FALSE.
$\Sigma_F = \Sigma_F + S$
638
Record a key frame:
$F_k = i$
648
$f_p = f_i; \Sigma_k = 0;$
$\Sigma_F = \Sigma_F + S$
$i = i + S$
No
a
i = EndFrame?
Yes
End

FIG.5 (continued)

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(54) A system for locating automatically video segment boundaries and for extraction of key-frames

(57) The present invention describes an automatic video content parser for parsing video shots such that they are represented in their native media and retrievable based on their visual contents. This system provides methods for temporal segmentation of video sequences into individual camera shots using a novel twin-comparison method. The method is capable of detecting both camera shots implemented by sharp break and gradual transitions implemented by special editing techniques, including dissolve, wipe, fade-in and fade-out; and content based key frame selection of individual shots by analysing the temporal variation of video content and select a key frame once the difference of content between the current frame and a preceding selected key frame exceeds a set of preselected thresholds.

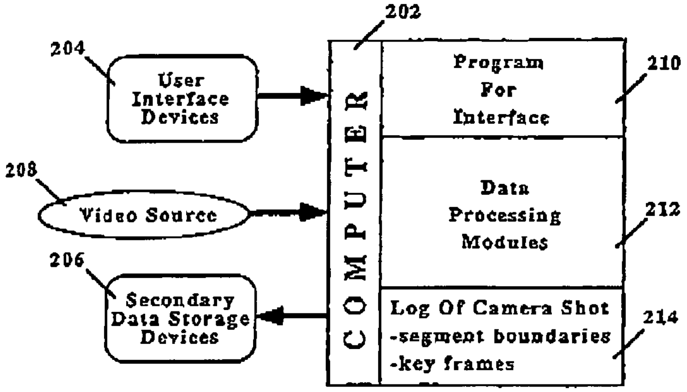

FIG. 2

EP 0 690 413 A3

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 30 4387

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	MULTIMEDIA SYSTEMS, vol. 1, no. 1, 1993, pages 10-28, XP000572496 ZHANG H. J. & AL: "Automatic partitioning of full-motion video" * page 12, right-hand column, paragraph 2 - page 15, right-hand column, paragraph 3.2 * * page 17, left-hand column, paragraph 4 - page 19, right-hand column, paragraph 5 * * page 26, right-hand column, paragraph 6 - page 27, right-hand column, paragraph 6.2 * ---	1-10	G06T7/20 G11B27/10 G06F17/30
A	EP-A-0 555 873 (INTEL CORP) 18 August 1993 * the whole document * -----	1-10	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			G06F G06T

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	4 June 1996	Fournier, C

CATEGORY OF CITED DOCUMENTS

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